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by

B. M. Bulakh

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Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
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К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

VORTICAL INTERACTION OF A SPATIAL LAMINAR BOUNDARY LAYER ON A CIRCULAR CONE WITH THE EXTERNAL (NONVISCOUS) FLOW AT SUPERSONIC SPEEDS

B. M. Bulakh

We have detected the phenomenon of a vortical interaction of a boundary layer and external flow with moderate supersonic speeds. It was shown that for a circular cone the phenomenon of vortical interaction is described by a self-modeling solution.

We are examining the problem of a boundary layer on a circular cone, streamlined by a uniform supersonic flow of gas under the angle of attack α. The author established earlier (in a work published at the MZhG) that in a system of spherical coordinates r, θ, φ, where axis $\theta=0$ coincides with the axis of symmetry of the cone, the behavior of density ρ, component of speed u, w, in the direction of an increase, respectively, of r and φ in the vicinity of the surface of the cone is determined by the formula

$$f=f_0(\varphi)+f_1(\varphi)(\theta-\theta_k)^B+\dots, \quad (1)$$

where $f=\rho, u, w$; f_0, f_1 - some functions of φ; θ_k - angle of the partial opening of the cone; B - the constant which in the majority of

cases is less than a unit; a dotted line designates the members of a higher order of smallness with respect to $\Theta-\Theta_k$, than those given. For cases of B<<1 the nonviscous flow near the surface of the cone whirls powerfully, which renders a significant influence on the boundary layer. If Re is the Reynolds number of the problem, $\varepsilon=(Re)^{-1/2}$ then in the system of coordinates where s is read off from the top of the cone along its generatrix, n - along the normal to the surface of the cone, the solution to the problem on the boundary layer has the form:

$$\left.\begin{aligned} u&=u_1(\zeta,\varphi)+\varepsilon^B s^{-B/2} u_2(\zeta,\varphi)+o(\varepsilon^B),\\ w&=w_1(\zeta,\varphi)+\varepsilon^B s^{-B/2} w_2(\zeta,\varphi)+o(\varepsilon^B),\\ v&=\frac{\varepsilon}{\sqrt{s}}\left[V_1(\zeta,\varphi)+\varepsilon^B s^{-B/2} V_2(\zeta,\varphi)+o(\varepsilon^B)\right],\\ \rho&=\rho_1(\zeta,\varphi)+\varepsilon^B s^{-B/2}\rho_2(\zeta,\varphi)+o(\varepsilon^B),\\ T&=t_1(\zeta,\varphi)+\varepsilon^B s^{-B/2} t_2(\zeta,\varphi)+o(\varepsilon^B),\\ p&=p_1(\varphi)+o(\varepsilon^B), \end{aligned}\right\} \qquad (2)$$

here u, v, w - components of the speed of particles of gas in the direction of an increase, respectively, of s, n, φ; ρ, p - density and pressure, T - absolute temperature: $\zeta=\frac{N}{\sqrt{s}}, N=n\varepsilon^{-1}$.

The members with subscript "1" in formulas (2) give the known (self-modeling) solution to the problem of boundary layer; members with subscript "2" occur as a result of the vortical interaction of the external flow and the boundary layer. Equations for $u_2, \rho_2, w_2, t_2, V_2$ are analogous to the equations for $u_1, \rho_1, w_1, t_1, V_1$ boundary conditions are different; therefore they are given thusly:

$$\begin{aligned} &\zeta=0, && u_1=V_1=w_1=0, \quad t_1=T_w, \\ &\zeta\to\infty, && u_1\to u_0(\varphi),\ w_1\to w_0(\varphi),\quad t_1\to t_0(\varphi); \\ &\zeta=0, && u_2=V_2=w_2=0,\quad t_2=0, \\ &\zeta\to\infty, && u_2\sim A_1(\varphi)\zeta^B,\ w_2\sim A_2(\varphi)\zeta^B,\ t_2\sim A_3(\varphi)\zeta^B. \end{aligned}$$

Here functions $u_0, w_0, r_0, A_1, A_2, A_3$ are determined from the solution to the problem for the external, nonviscous flow; T_W - temperature of the surface of the cone. An indirect evaluation of the value of a check for the results of the normal theory of the boundary layer due to the vortical interaction can be done by means of evaluating the multiplier ε^B in formulas (2).

For example, for the Mach number of an undisturbed flow M=5 $\theta_k = 20^\circ, \alpha = 10^\circ, B \approx 0.33$; for values M=7 $\theta_k = 30^\circ, \alpha = 5^\circ, B \approx 0.075$; if we take $Re = 10^6$, then $\varepsilon = 10^{-3}$ and for the modes given above the flows of the cone are, respectively:

$$\varepsilon^B \approx 0.1 \text{ and } \varepsilon^B \approx 0.6.$$

Consequently, we can anticipate that the corresponding checks are achieved in a number of cases to tens of percents.

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